SORGHUM-SIRUP MANUFACTURE

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THIS BULLETIN describes the varieties of sorghum and tells how to plant, cultivate, and harvest the crop. It gives the methods for manufacturing sorghum sirup, often incorrectly termed sorghum "molasses," with illustrations of the apparatus used. The approximate yields of cane, of sirup, and of sorghum seed are given. Economic considerations as to the location and arrangement of a sorghum-sirup plant, fuel used, the by-products and their uses, and making sirup on shares are set forth. Tables showing the sugar content of juice from typical varieties of sorghum cane and statistics for the yield of sirup by States from 1859 to 1909 are included.

The bulletin should be of value to farmers in the sorghum-producing sections of the country and to manufacturers of the sirup.

SORGHUM-SIRUP MANUFACTURE.

CONTENTS.

USE OF SORGHUM FOR SIRUP.

SORGHUM is more widely distributed than sugar cane or sugar beets, gives large yields per acre, and is easy to cultivate; at the same time it has a relatively high sucrose content. When the extension of the sorghum industry was first advocated, therefore, it was thought that this crop would play an important part in supplying the nation with sugar. Experiments showed, however, that the juices of this plant, while rich in sucrose, contained some reducing sugars, as well as a fairly large percentage of gums and gummy material which upon concentration retarded the crystallization of sucrose or cane sugar. It was also found that the yield of crystallizable sugar was low in comparison with that of sugar cane and sugar beets. At the close of these experiments the use of sorghum cane for the production of sugar was dropped to a great extent, but the plant continued to be used in making sirup. Although at the present time little or no sugar is derived from sorghum cane, the manufacture of sorghum sirup is an important industry in many States. The average quality of the sirup now produced is superior to that of sirup formerly made. This is doubtless due to the fact that modern evaporators enable the manufacturer to produce a lighter colored, better flavored sirup than was possible with the old-fashioned kettles and pans.

The terms "sirup" and "molasses," often used interchangeably in connection with sorghum, denote altogether different products. Sorghum sirup is the concentrated juice of the sorghum plant with

or without the addition of the usual clarifiers, while sorghum molasses is the liquid residue coming from the draining or centrifuging of sorghum sugar. As very little, if any, sorghum sugar is manufactured to-day, the product of farm manufacture could hardly be termed "sorghum molasses." This confusion of terms may be due in part to the fact that molasses is generally heavy and thick, while sirup is lighter and thinner. Ordinary sorghum sirup is heavy in appearance, due to the gummy material present, resembling molasses more than it does a maple or cane sirup of equal density.

The manufacture of sorghum sirup is not a complicated process requiring special skill. It does not necessarily call for expensive apparatus or machinery nor are dangerous chemicals employed. The processes to be described are simple, but as in all sugar or sirup making cleanliness and dispatch are necessary, and unless one is very careful, numerous unsuccessful trials may be made before a fine sirup is produced.

VARIETIES OF SORGHUM.[1]

In the broad sense of the word, sorghum includes all the groups popularly known in this country as sorgo, sweet sorghum or saccharine sorghum, kafir, broom corn, shallu, kowliang, durra, and milo, but only the first group is of practical interest. Saccharine sorghums are recognized by their sweet sap or juice. They are, as a rule, tall with a leafy growth, branching only sparingly at the upper nodes or joints, and not stooling much at the base under ordinary cultivation. The seed head varies from the close compact "club" head of the Sumac sorghum through the rather more open heads of Orange and Gooseneck, to the loose and often widely spreading heads of the Amber and Honey varieties.

Beginning with the original importation of a single variety of Chinese origin in 1853, there were in 1906 probably no less than 200 so-called varieties in cultivation. Most of them, however, never attained any prominence outside of the locality where they originated. Ball has divided the sweet-sorghum varieties into three or four groups, each consisting of a single well-marked variety and a number of forms derived from it. Such groups are the Amber, Orange, Sumac, and Gooseneck sorghums.

AMBER SORGHUM.

Amber sorghum is said to have developed in Indiana from the original Chinese sorghum. It is an early variety and is sought for that reason. It soon was called Early Amber, and when the seed came from Minnesota was known as Minnesota Early Amber. From 70 to 100 days are necessary for the Amber sorghum to reach matu-

[1] The notes and description of varieties are taken in part from Farmers' Bulletin 246, "Saccharine Sorghums for Forage," by Carleton R. Ball.

rity, the time varying according to the latitude, season, and soil. It is characterized by the rather slender stalks and comparatively few and narrow leaves; the seed heads are generally black in color, varying in shape and size, and rather loose (fig. 1). One variety of this

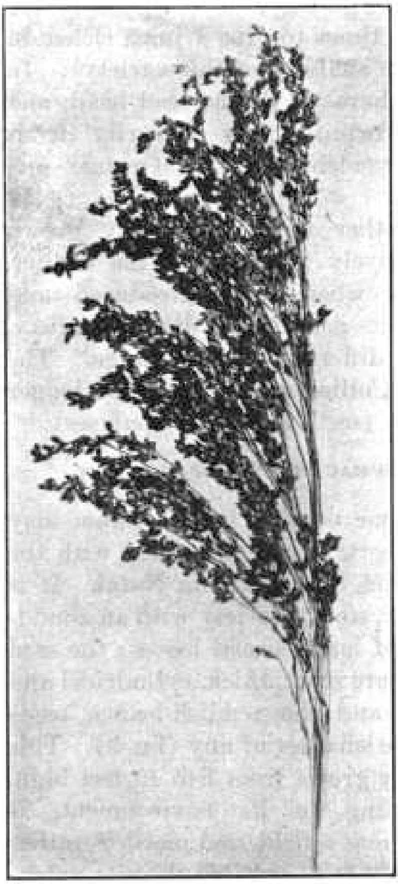

FIG. 1.—A head of Amber sorghum (about one-fourth natural size).

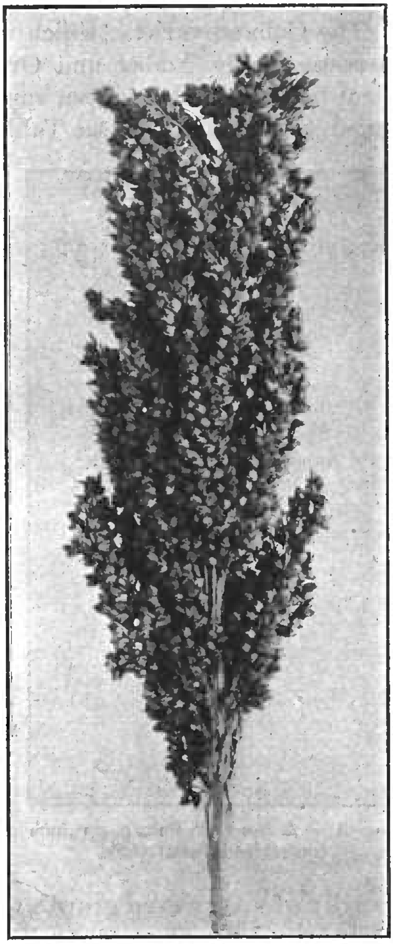

FIG. 2.—A head of Orange sorghum (one-half natural size).

Early Amber, known as Folger, is a strain originated as an improved sirup variety having all the characteristics of Amber sorghum. Other varieties of some prominence are the Red Amber and the Minnesota Amber.

ORANGE SORGHUM.

Orange sorghum which is of South African origin differs from the Amber variety in having larger and heavier stalks, larger and more abundant leaves, and heavier and more compact seed heads (fig. 2). The seeds just before ripening are almost white. The

Early Orange, as this standard variety is usually called, requires about two or three weeks longer than the Amber to reach maturity. On account of its growing taller and the stalks larger, it gives a slightly heavier yield per acre. Various forms of this variety are offered on the market, including Kansas Orange and Late Orange.

The Colman variety, which is said to have originated as a hybrid between Early Amber and Orange sorghum, is used by many for sirup making and has been shown at times to give a juice richer in sugar than any other (see Table 4 for analyses of this variety). In size, character of the seed head, and time required for maturity it is almost identical with Orange sorghum.

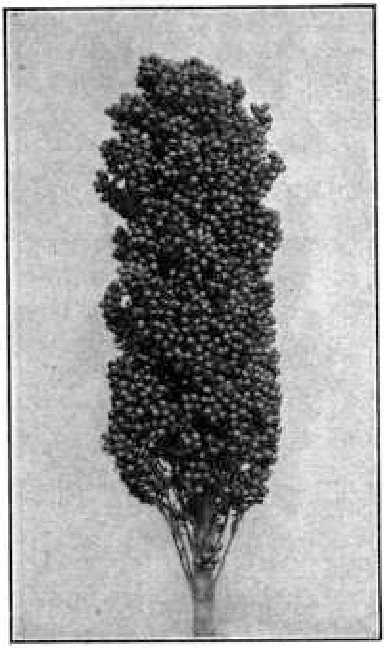

FIG. 3.—A head of Sumac sorghum (one-third natural size).

Another variety formerly grown extensively for sirup is the Collier, which when first introduced and given its name was a distinct variety, quite different from Orange. The pure Collier seems to be no longer grown (see Table 4 for analyses).

SUMAC OR RED-TOP SORGHUM.

Sumac or Red-Top sorghum may quite certainly be identified with the varieties brought from Natal. It is a stout, stocky variety with an abundance of large, broad leaves; the seed heads are stout, thick, cylindrical and erect, and the reddish-brown seeds are the smallest of any (fig. 3). This variety grows from 7 to 10 feet high, according to its environment, is usually of a very even growth throughout a field, and matures rather early, requiring from 90 to 120 days. It is cultivated quite extensively in the South.

GOOSENECK SORGHUM.

Gooseneck sorghum is distinct from any of the others grown in this country and is thought to be a direct descendant from one of the original African varieties. Its name is probably derived from the recurved and pendent stems, reddish in color (fig. 4). It grows commonly from 10 to 12 feet high and when thinly sown, for sirup making, the stalks are from 1 to 1½ to 2 inches in diameter at the butt. This variety was extensively grown in the South, especially

Texas, but being a much later ripener than Amber and a week or 10 days later than Orange and Sumac, it can not be grown in the Northern States.

HONEY SORGHUM.

Another variety of some prominence is the Honey. Its origin can not be definitely traced, but no doubt it came from an African importation. The stalks are from 7 to 10 feet high, averaging 13 to 18 nodes in different localities, are stout, from 1 to $1\frac{1}{2}$ inches in diameter at the base, and very sweet. The stems are markedly tender in comparison with other stout varieties. It is, however, a very late ripener, requiring from 130 to 140 days to mature, and therefore is best adapted to the South.

FIG. 4.—A head of Gooseneck sorghum (one-third natural size).

SELECTION OF A VARIETY.

From the preceding discussion it is seen that for northern regions, where the growing season is short, some form of Early Amber or of Early Orange, preferably the former, must be selected, while farther south all the varieties may be used. A variety grown one season may produce a good sirup, but under different climatic conditions another year may not yield so good a product. The nature of the season seems to exert a marked influence on the composition of the plant, as has been definitely determined in the case of other sugar-bearing crops.

When a variety has repeatedly given good yields and a good quality of sirup, the seed should be carefully selected for replanting. To do this, place several typical canes[1] in shock, cover them with a net or other protection from birds, and when quite dry cut the seed heads and place them in a stout grain bag. The seed can be threshed by pounding with a club and cleaned by pouring from one pan to another in a gentle breeze. Stems and trash can be removed from the seed by shaking the pan and picking them out as they come to the surface. In this way an unmixed seed of good quality can be obtained by the sirup maker.

[1] Comparison of the size of seed head and sugar content of stalk has led to the generalization that individual cane with larger seed heads than their fellows have a lower content of sugar. (A. A. Denton) U. S. Dept. Agr., Bureau of Chemistry Bul. 26, p. 94.

CULTURE OF SORGHUM.[1]

While sorghum is a crop generally thought to require little attention, its yield and value can be materially increased by using care in its culture. Good seed of the right variety is necessary for the best yields, but there are other equally important factors that must not be neglected, such as preparation of the soil, time and rate of seeding, and manner of planting. Perhaps more failures to secure satisfactory crops are due to improper seeding than to any other cause, and too great care can not be given to planning for and planting the crop.

PREPARING THE SEED BED.

Although a large portion of the land planted to sorghum is left unplowed until a short time before seeding, this practice is by no means advisable. For the best yields there must be a firm seed bed, obtained by plowing the land early in the fall and harrowing or disking to keep down weeds until seeding time. Such preparation allows whatever vegetation there may be in the soil to decay and leaves it in the best tillable condition. In the drier regions this treatment serves to take in and retain any moisture that may come during the winter season and to decrease the chance of failure from drought. In the same manner it increases the yield in more favorable seasons. In the more humid sections early preparation is preferable, though not so necessary as in the drier regions. The land is sometimes prepared by "bedding" or listing with a middle buster or a turning plow.

PLANTING.

The planting of sorghum deserves more careful attention than any other operation entering into the production of the crop. The time, method, and rate of seeding mean success or failure in the degree in which it has been properly or improperly done. It is therefore of vital importance that the farmer attend carefully to the planting of his crop.

Time of planting.—The sorghums are usually planted soon after corn, when the ground is thoroughly warm. They may be planted at any time after that date until as late as will permit the crop to mature safely. In the Southern States the first of April is considered early planting. Northward, using the northern line of Louisiana as a base, the season grows later at the rate of about one week for every 2 degrees, or 150 miles. Early seeding is preferable for the reason that it may produce a second crop which can be used for forage. It is usually well to make two or three different plantings at intervals of about ten days or two weeks so that all the crop will not mature at the same time.

[1] This section was prepared by A. B. Connor, Bureau of Plant Industry.

Method of planting.—For sirup production sorghum should always be planted in rows 3 or 3½ feet apart. This may be done with a single or double row planter either on a bed, on the surface, or in a lister furrow, depending on the section where the crop is grown. Furrow planting is most common in the drier regions, but it is practiced to some extent in the humid sections. In some of the lower and poorly drained lands planting is made on a bed, but only under such conditions should this method be used.

Rate of seeding.—The rate and regularity of seeding largely influence the yield of sirup regardless of the method used. Seeding should be done so that the plants will be very evenly distributed and average a distance of 4 to 6 inches in the row, or even more in the drier regions. It is possible to make a special plate for the drill that will plant the crop very satisfactorily and thus avoid a great deal of labor in thinning. The quantity of seed required to plant an acre is small, varying from 2 to 8 pounds, depending upon rate and method of planting.

CULTIVATION.

While sorghum will grow and give fair yields with little or no cultivation, this is by no means the most profitable method of producing the crop. Careful cultivation has repeatedly been known to increase materially the yield per acre. The first cultivation can be given with a spike-toothed harrow, and as soon as possible afterward it should be cultivated deeply with sweeps or shovels. Later in the season at least two additional shallower cultivatings should be given for the best results. Sorghum can be cultivated to advantage until it begins to put out heads, provided care is taken not to destroy the surface feeding roots.

HARVESTING.

The stage at which the sorghum contains its greatest sugar content, a matter of the greatest importance to the sirup maker, has been the subject of much investigation in former years. Collier gave the following figures as a result of about 2,740 analyses of sorghum canes made at different stages of growth:

TABLE 1.—*Sugar content of sorghum at different stages of growth.*[1]

Stage of cutting.	Sucrose.	Invert sugar.
	Per cent.	*Per cent.*
Panicles just appearing	3.51	4.50
Panicles entirely out	5.13	4.15
Flowers all out	7.38	3.86
Seed:		
In milk stage	8.95	3.19
Doughy, becoming dry	10.66	2.35
Dry, easily split	11.40	2.03
Hard	13.72	1.56

[1] Peter Collier, Sorghum: Its Culture and Manufacture (1884), 198.

From these figures it appears that from the time the seed is in the late milk stage until it is becoming dry the cane is in the best condition for sirup making. Some prefer to wait until the seed is hard before cutting, as the sugar content is still higher then, but they run the danger of a frost before all of the cane is worked up.

Cutting can be done by hand or by a harvester. When harvested by hand, the individual canes are cut about 6 or 8 inches above ground and laid across the rows with all the heads in the same direction. With a harvester and binder the cutting and binding in bundles forms one operation, and all the seed heads are at one end of the bundle. It is customary among some makers to leave the hand-cut cane in the field for a day or two to wilt the leaves, which is said to improve the quality of the sirup. The seed heads are removed and left in the field to be collected after the harvest. For a good grade of sorghum sirup all leaves and seed heads must be removed from the cane, as these on passing through the mill tend to impart a bad flavor to the juice and resulting sirup, introduce more or less dirt and fine particles of plant material into the juice, and retard clarification. Moreover, leaves which have become dry have a tendency to absorb juice as it is pressed out in the mill, thus decreasing the yield of juice and sirup. In removing the seed heads, about 6 to 18 inches of the upper cane should be cut off, as this part contains little sucrose and many impurities; suckers should also be discarded for the same reason.

The harvesting should progress in proportion to the mill work, no more being cut at one time than can be worked in two days. When the weather is cold the cane may be cut and shocked. Some makers have kept it in shock for four weeks with no appreciable loss in sirup-making properties. Like other sugar-producing plants, however, a freeze does not hurt the crop, provided the cane can be worked up just as soon as it thaws. On freezing the cells of the cane are broken, and on thawing, decomposition quickly sets in. A frost will not hurt a ripe cane materially, but if the cane is immature it will be spoiled. Frosted cane, like frozen cane, should be worked up as soon as possible. In Louisiana the sugar cane is "windrowed" when a frost or freeze is expected—that is, the cane is cut and laid on the ground between the rows, the leaves serving as a protection. In the case of sorghum, under such conditions, if the weather is warm during the middle of the day, the leaves on the stalk soon produce a "heating" of the pile and decomposition sets in. "Heated cane" and frosted cane do affect the flavor of the sirup. One of the large makers states that by shocking the cane with leaves and heads on he has kept it in good condition for many weeks. This, of course, was during cool weather, for even when standing in shocks the cane is liable to "heat."

As stated before, for sirup making the best stage for cutting is just before hardening of the seed. Earlier than this the cane is too green and the resulting sirup will have an unripe taste. If cut when the seeds are very hard, the juice is said to be difficult to clarify, and the flavor of the sirup is not good.

On the subject of yield but few definite data can be given, as so many factors influence it. Sorghum may yield as high as 15 tons to the acre or as low as 4 or 5 tons; an average crop is about 8 or 10 tons. The gallons of sirup per ton of sorghum depend on the kind of mill and on the care in manufacture, also the ripeness and kind of cane. A ton of cane with a 3-roller mill should yield anywhere from 700 to 1,200 pounds of juice, giving 8 to 30 gallons of finished sirup, depending upon the richness of the juice. Taking 10 tons per acre as the average yield, from 60 to 300 gallons of sirup per acre should be obtained. Information from farm producers of sirup, however, indicates that the usual yield is from 110 to 200, with an average of 155, gallons per acre. A greater yield is usually secured at large plants where the juice is extracted by passing the cane through a series of 3-roller mills and where the evaporators make for efficiency. At these mills a larger proportion of juice is extracted and less loss during evaporation and skimming occurs than is the case in smaller plants. At one large mill the yield of sirup varied from 180 to 220, with an average of 200, gallons per acre. Large amounts of juice are lost in the mills and again in skimming.

MANUFACTURE OF SORGHUM SIRUP.

This discussion is designed for the benefit of the small makers of sirup rather than for those having large, well-equipped plants.

EXTRACTION OF THE JUICE.

The ordinary method of obtaining juice from sorghum cane is by pressure—that is, running the cane between iron rollers set at a certain distance apart. Another method is by diffusion, a process in which the cane is first finely shredded and placed under pressure with water in large tanks, the water removing the sugar and soluble material. This method requires very expensive machinery and much experience, and is not used now by any sorghum-sirup makers, although it is the ordinary process for extracting the sugar from beets.

The primitive mills were made by placing two logs upright side by side in a heavy frame. To one of the logs, extending above the frame, was attached a large sweep. On turning this and feeding the cane between the rollers, the juice was squeezed out. It does not extract more than 25 or 30 per cent of the juice, and hence has little com-

mercial value. It is doubtful whether this kind of mill is used at the present time. The wooden rollers of this form have been replaced by iron rolls, and to-day many makes of 2-roller mills are found on the market. The extraction with these is better than with the wooden rollers, but does not equal that of the 3-roller mill. The latter can be obtained with the rolls upright or horizontal. The smaller mills are operated by horses or mules, the larger ones by steam or water power. Figure 5 gives a view of a 3-roller upright mill with a shaft for a sweep operated by horsepower. Figure 6 shows a 3-roller horizontal mill for horsepower. These mills can be provided with smooth or serrated rolls. In the upright position the serrated rolls prevent the cane from twisting to one side. A good mill should be easily taken apart and new pieces substituted when breaks occur; it must run smoothly and true for good results. The rolls must be capable of adjustment to any distance from each other. In setting up such mills, care should be exercised to have the mill level and rigid on the frame or upright supports, which should be carefully braced. Without these precautions, imperfect pressing will result and a break in the mill may be caused. Figure 7 shows a power mill. These are made either single or double geared, so that they can be connected direct with some form of farm engine. Figure 20 (p. 28) shows a power mill driven by a traction engine. Power mills are to be preferred to the horse mills, as the crop can be worked up more easily and quickly. Figure 8 shows a power mill fitted with a feed table and a bagasse carrier. The former is an important adjunct to a milling outfit, especially for a power mill, as it allows the cane to be arranged in some order before entering the rolls, thereby assuring a more even feed. A bagasse carrier geared to the rolls delivers the bagasse some distance from the mill.

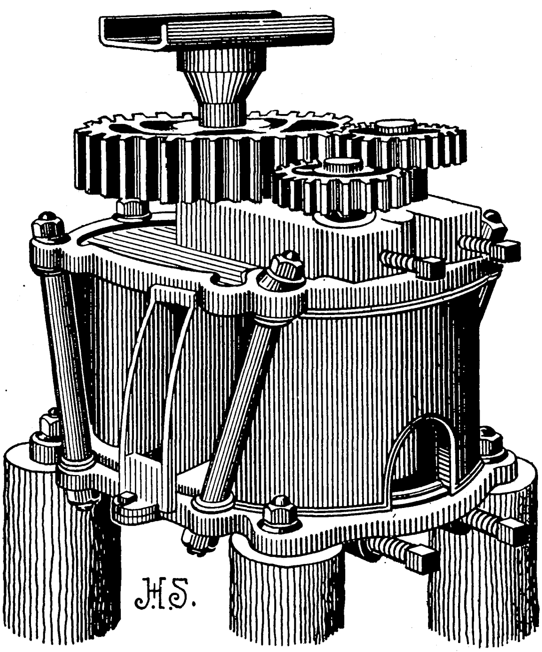

FIG. 5.—Heavy three-roller vertical horsepower cane mill.

In making sorghum on a large scale, two or more 3-roller mills may be used, one following the other. In this case, the crushed cane (bagasse) as it comes from the first 3-roller mill is often moistened slightly with water and then passed immediately into the second mill. This method increases the extraction.

Having selected a mill and set the rolls the next point to consider is how to feed the mill to obtain the best results from the cane. Sorghum ordinarily contains from 70 to 80 per cent of water and about 10 to 12 per cent of fiber, but it is not possible to obtain all of the water as juice. With a 3-roller mill, at least 50 per cent of the weight of the cane should be obtained as juice unless the cane is very hard and dry, and with a good mill and close setting 60 per cent is not too much to expect. The "feed," or amount of cane in the mill at one time, should be light or heavy according to the adjustment of rolls. When the rolls are set "open" or apart the feed should be heavy; when they are set close together the feed should be light; but in all cases it should be regular and uniform. It is evident that when the rolls are set "open" juice is wasted when the feed is light; with a close-set roll there is also a loss of juice when the feed is irregular and not even over the roll.

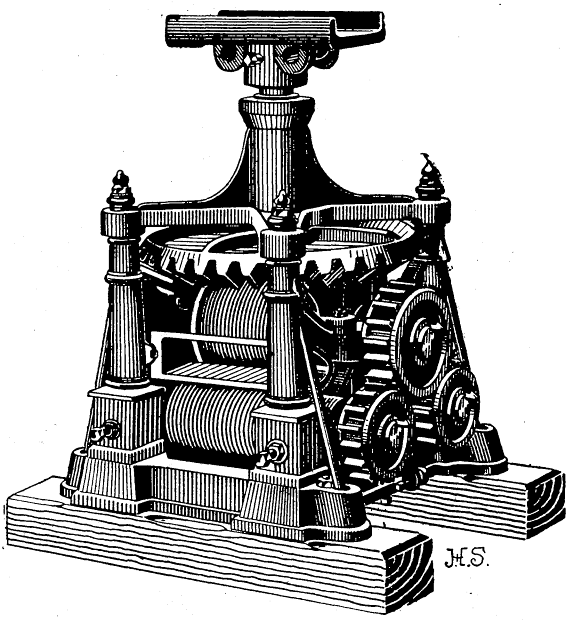

FIG. 6.—Three-roller horizontal horsepower cane mill.

Juice obtained by moderate pressing is purer than that obtained by extreme pressure, by which more impurities from the rind and joints of the cane are extracted. Sirup made from moderate pressing usually has a better flavor than that from the heavy pressing. Where cane is cheap and abundant it is inadvisable to increase the extraction of the juice greatly by excessive pressure.

SETTLING THE JUICE.

The raw juice coming from the mills should pass into collection or storage tanks. These may be merely rough barrels or metal or con-

crete tanks. Before entering these the raw juice should pass through a fine sieve or mesh screen to remove particles of cane, dirt, etc. There should be at least two tanks, one being filled while the other is emptied. A third tank is almost a necessity, as it allows time for the juice to settle. Raw sorghum juice holds mechanically in solution a number of impurities which on standing slowly settle to the bottom. If not allowed to settle they will collect in the evaporator at the point of entrance of the raw juice and may burn on the bottom of the evaporator. It is necessary, therefore, to remove as much as possible of this material before evaporation is begun. Heating the raw sor-

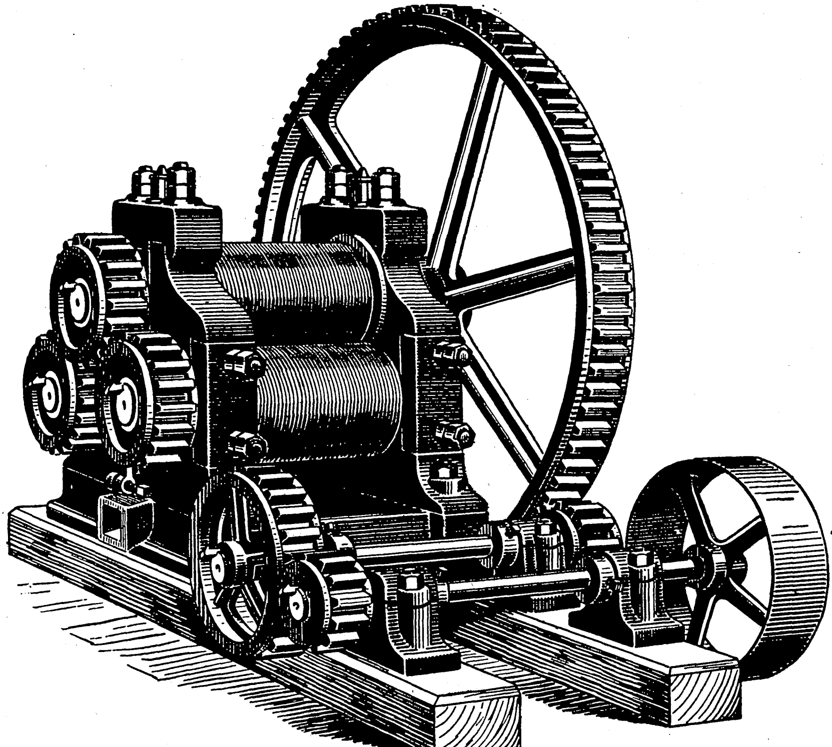

FIG. 7.—Three-roller power mill.

ghum juice tends to quicken the settling of the juices. Some makers use a small boiler or feed cooker (fig. 9) for this purpose; especially is this done when the evaporation is carried on by direct fire. In the case of steam evaporation the exhaust may be used to heat the raw juice. Other makers settle this material by means of clay added to the cold or hot raw juice. A. A. Denton[1] proposed that a heavy, finely divided clay be stirred in with the juice. This tends to surround the floating sediment and carry it to the bottom, but it requires the use

[1] U. S. Dept. Agr., Farmers' Bulletin 90.

of a heavy, coarse-grained clay, which is often not easily obtainable. An examination of some 200 samples of clay[1] collected from all over the country, showed in general: (1) That fire clays are too coarse grained and do not carry down the impurities; (2) that pure white clays are too fine grained and give bulky and indistinct settlings; (3) that blue clays, gumbo, or waxy clays are not suitable; and (4) that yellow or brown plastic clays are best. Still other makers pass the raw juice through filtering bags to remove the sediment, but this is rather tedious and does not always accomplish the purpose.

Settling tanks should be equipped with some arrangement for drawing off the clear juice without disturbing the settlings, or for drawing off first the settlings and then the clear juice. Figures 10 and 11 show such devices. Figure 10 shows a swinging barrel which

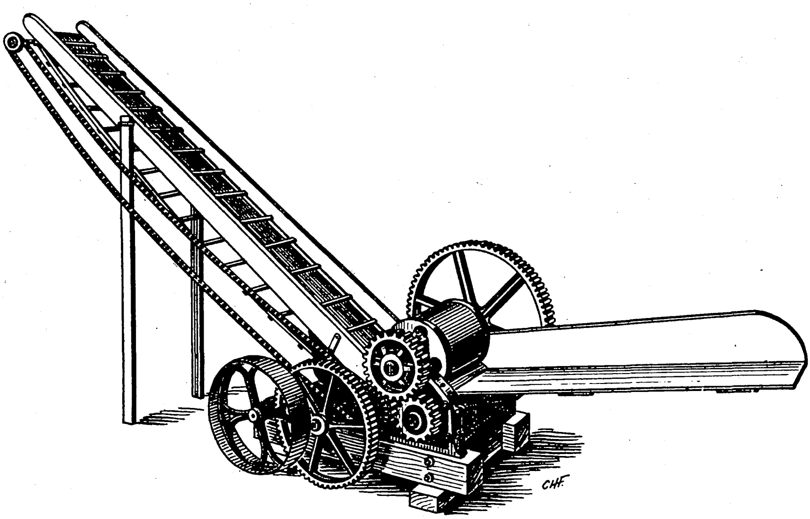

FIG. 8.—Mill with feed table and bagasse carrier.

can be used by manufacturers working on a very small scale. Connections suitable for tanks are shown in figure 11. Cut "A" shows an opening near the bottom fitted with a cock. By carefully opening this the turbid liquid is allowed to flow out into a small vessel and is turned into its proper tank when it begins to run clear. Cut "B" is a sliding overflow pipe, which passes through the bottom of the settling tank; by pushing the pipe down, so that its upper end is below the surface of the liquid, the clear juice is drawn from the surface down to the settlings. Cut "C" is an outside swing pipe, which draws the settlings from the bottom of the first tank, then the clear juice follows. When the long arm is turned down the liquid flows out; when it is turned up, the flow ceases.

[1] U. S. Dept. Agr., Bureau of Chemistry Bul. 37, p. 85.

Cut "D" represents possibly the best form for tanks. The swing pipe is placed inside the tank, and by keeping the upper end of the long arm just below the surface of the liquid the sediment is left behind. A float may be connected with the long arm, keeping it just below the surface of the liquid and arranged so as not to draw the settlings. The arm when standing erect must be long enough to reach above the surface of the liquid in the settling tank, and the swing pipe should be placed close to the bottom of the tank, far enough from the side to allow the long arm, when turned down entirely, to lie flat upon the bottom, in order to draw all the liquid as well as the sediment from the tank; the long arm of the nipple should fit the threads tightly enough to hold the weight of the pipe in any position and not allow it to drop down under any conditions. The settlings or sludge can be used for feeding hogs; but when the settling has been done hastily the sludge should be drawn off to another tank and allowed to settle more slowly, thereby saving more of the juice.

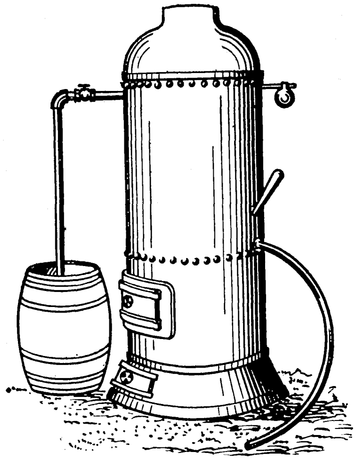

FIG. 9.—Feed cooker for heating juices.

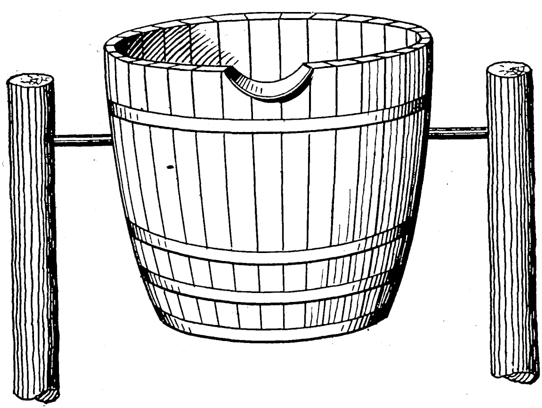

FIG. 10.—A swinging barrel for easily pouring off settled juice.

CLARIFICATION OF THE JUICE.

Clarification is designed to remove the objectionable substances from the raw juice so that a better grade of sirup may be obtained. The impurities in sorghum juice vary, depending on the season, variety of cane, pressure used in extraction, and the ripeness or condition of the cane. The undissolved impurities are removed to a great extent by settling, but those going into solution must be removed by heat or some chemical treatment. The addition of chemicals, however, while tending to throw certain impurities out, gen-

erally leaves in their place part of the foreign substance added and very often completely changes the flavor of the resulting sirup. Many schemes and many substances have been proposed for clarification. Some do the work, while the use of others is questionable.

It is suggested that as a general thing the small producer of sirup should not attempt to employ chemical methods of clarification. Great care must be used in adding chemicals for this purpose, as a

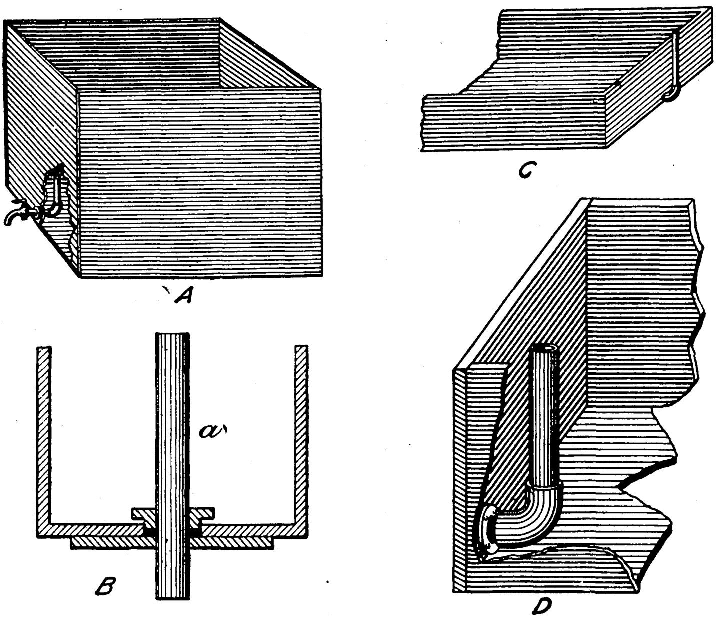

FIG. 11.—Tank connections for drawing off juice. *A*—A settling tank from which the clear liquid is drawn by an upright nipple near the bottom. *B*—A sliding overflow pipe for decanting liquids. *C*—An outside swing pipe for drawing liquid from the bottom. *D*—An inside swing pipe for decanting liquids from near the surface.

slight excess of certain substances may ruin the color and flavor of the sirup. Allowing the juice to come in contact with iron surfaces should be avoided as far as possible, for iron tends to darken the color of the sirup.

HEAT ALONE.

When the raw juice is heated a coagulation of the albuminous matter which rises to the surface and can be skimmed or brushed off occurs. In coagulating, this material tends to remove some, and generally most, of the suspended matter. Some makers provide special pans or tanks for this heating or clarification; the temperature of the juice is brought nearly to the boiling point and the heat then is turned off and the juice allowed to stand; the clear layer is then

drawn off for evaporation. This process, which is to be preferred especially in the manufacture on a small scale, is also commonly used in cane-sirup manufacture.

HEAT AND LIME.

At certain seasons, and with certain varieties of cane, the raw juice may be high in acid. To partially neutralize this acidity, lime is added by some makers. This also tends to precipitate some of the organic matter. It is a question, however, whether by its use any more of the organic impurities are removed from the raw juice than by heat alone. The procedure when lime is used is as follows:

Slack completely a quantity of lime with water and then add more water to produce a thin whitewash. Strain the whole through a mesh screen, $\frac{1}{8}$ inch or even finer, to remove lumps, unburnt stone, etc. If still too thick, dilute with water. Add only enough of this solution to almost neutralize the acidity, this point to be determined by testing the juice before and after adding the lime (the whole being stirred thoroughly) by the following method: Dip a piece of blue and a piece of red litmus paper in the solution; if it is acid, the blue litmus paper will turn red and the piece of red litmus paper will remain unchanged; if the solution is alkaline, the opposite occurs, namely, the blue litmus paper remains unchanged in color while the red litmus paper turns blue. If neither one is affected, the solution is said to be neutral in reaction.

It is far better to lime lightly at first, noticing the color of the juice after the addition of lime, the tint of the blue litmus paper after wetting it in the thoroughly stirred limed juice, and the quality of the sirup produced; then add more or less lime to the next lot of juice, keeping always on the safe side—that is, the acid side. Liming should cease when the juice gives only a faint red to litmus. If it does not change the color at all, too much lime has been used, and fresh unlimed juice should be added.

Litmus paper can be obtained in "books" or in sheets. The former is a little more expensive but is easier to use. If sheet litmus is used, a piece should be cut for immediate use, clipped into small oblong pieces, and put into a small bottle, which may be corked and carried in the pocket. The rest of the sheet should be put away in a corked bottle for future use. Acid vapors in the air and fingers moist with acid juices redden and spoil blue litmus. By moistening the tip of the finger and touching one of the pieces of the blue paper it may be picked up without handling the others. In using lime for clarification the greatest care must be taken not to render the juice alkaline by the addition of an excess, which would spoil the flavor and color of the sirup.

OTHER METHODS OF CLARIFICATION.

Use of phosphoric acid compounds.—In this treatment two methods of procedure have been used. In one the phosphoric acid is added to the raw juice and then limed before heating. In the other lime is added to alkalinity, then phosphoric acid is added to a slight acidity, and the juice is heated. This procedure greatly changes the flavor of the resulting sirup, and its use is very questionable.

Use of lime carbonate or whiting.—Ordinary slacked lime is strongly caustic, while carbonate of lime or whiting is not, so less care is necessary when using whiting to avoid an excess. In using this material heat the juice and sprinkle the carbonate over the surface, reheat and sprinkle again, noting the reaction to litmus of the resulting solution. Much more whiting than lime is necessary to neutralize the acidity. Whiting can be added to settling juice to cause a better and quicker separation of the precipitated and suspended material. As in the case when lime is used, the greatest care must be taken not to render the juice alkaline.

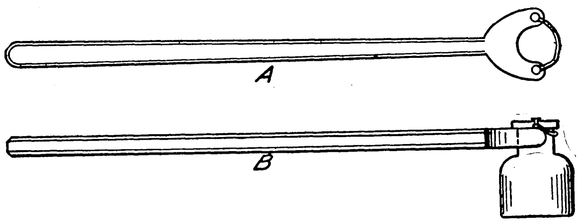

FIG. 12.—Test glass with cut of handle.

TEST GLASS AND ITS USE.

As a means of watching the progress of clarification, a test glass may be used to withdraw samples and examine them by transmitted light. Prepare a handle from a ½ to ¾ inch board about 2 feet in length and notch it as shown in figure 12. Obtain a 2 or 4 ounce wide-mouth glass bottle from a drug store and place it in the notch, then by means of a strip of sheet iron bind the bottle in place. This will be found very convenient at various stages of sorghum-sirup manufacture.

EVAPORATION OR CONCENTRATION.

The object of the process of evaporation is to remove the water from the raw juice and thereby thicken it to a sirup. This thickening may be carried to a half concentration, filtered, and the concentration completed. This procedure is quite often followed in manufacturing on a large scale, in making a sirup from overripe or underripe cane, or when much lime has been used in clarification.

USE OF KETTLES.

The simplest form of boiling apparatus is the old iron kettle. One of these may be swung from a chain or pole, or several may be arranged in a row as a battery, generally called a "Jamaica train," as shown in figure 13. The fresh juice is placed in the kettle next to the chimney and as it heats it is ladeled into the next one. The finished sirup is taken from the kettle immediately back of or over the fire box. When a single kettle is used a fire is built around the outside of it, the raw juice is poured in, and the kettle is swung in to the fire. Concentration in this form of apparatus seldom yields light-colored, good-flavored sirup. The greatest care must be used not to allow the flame to get above the level of the juice in the kettle, otherwise it will burn and have a scorched taste. Another precaution necessary when making sirup in this kind of an apparatus is to concentrate a single charge and not to add fresh juice to the boiling sirup. The latter procedure always gives a dark-colored sirup with a strong burnt flavor. After a charge has been concentrated, the kettle should be swung from the fire and the sediment washed out before it has had time to burn. If the kettle can not be removed from the fire, after two or three charges, remove the fire and clean the kettle.

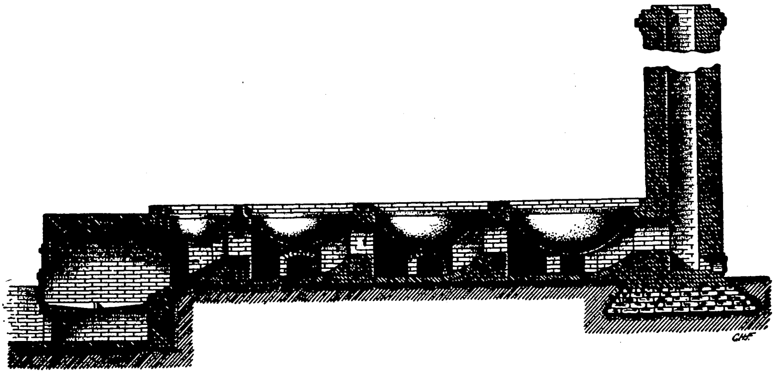

FIG. 13.—Jamaica train of kettles.

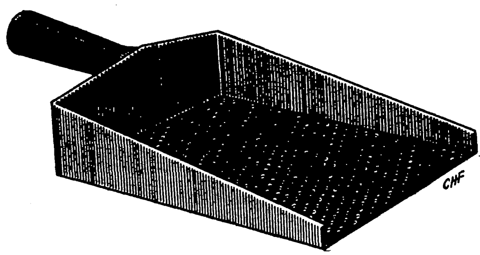

FIG. 14.—A sirup skimmer.

Any scum collecting on the surface of the boiling liquid should be removed as it forms. This is easily done with a skimmer. A sirup skimmer is made of metal, and resembles an ordinary dustpan, with the bottom perforated. It may have a short handle, as shown in fig-

ure 14, or a long wooden pole may be attached to it. Another form of skimmer often used is a pole with a narrow piece of metal fastened to it toward the end. By means of this the scum can be raked to the near edge of the pan and then be lifted off by the regular skimmer.

PANS AND PATENT EVAPORATORS.

Instead of kettles many makers use shallow pans (not over 4 to 6 inches deep) made of sheet iron, galvanized iron, or heavy tin. In this case a single pan covers the whole space occupied by the kettles or two or three pans may be used, one back of the other. These may or may not be connected so that the juice can flow from one to another. Figure 15 shows a single pan with strips to guide the juice over a zig-zag course during boiling. The raw clarified juice comes in at the fire end and the finished sirup runs out at the chimney end. In most cases these pans are lifted from the fire for cleaning at the end of the day.

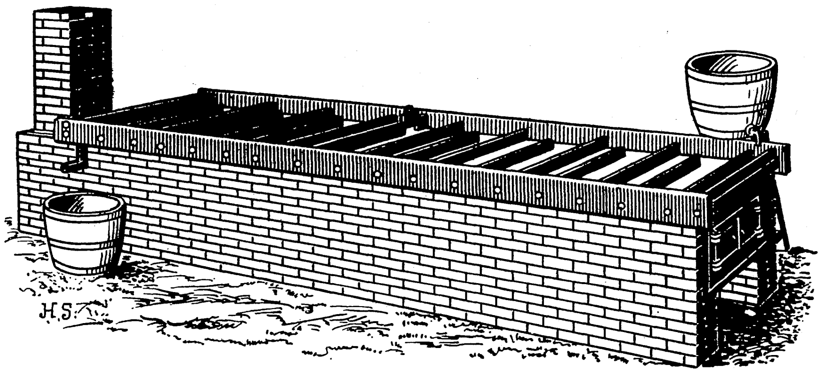

FIG. 15.—A pan evaporator.

Many improvements have been made in late years in the evaporation apparatus. Patent evaporators have many points of superiority to recommend them. The bottoms are usually corrugated to give a larger heating surface, the various compartments are connected, and an automatic supply valve is placed so that the depth of the liquid in the evaporator can be regulated. Their construction is such as to produce a quick concentration without the danger of burning or scorching the sirup.

Some makers prefer a homemade pan constructed of $1\frac{1}{2}$-inch boards with a sheet-iron bottom carefully luted to the sides. This form of pan can not be recommended under usual conditions for making a good grade of sirup. After once using the wood becomes soaked with the juice, and if allowed to stand empty this juice sours and taints the next boiling. In the long run they are more expensive than iron pans, as the wood soon warps, the joints become loose, and sirup is lost.

Figure 16 shows a portable evaporator which can be easily transported from one place to another and also tilted to allow a flow of juice and sirup. It is used quite extensively in some sections of the country.

When using these forms of evaporators only a thin layer of sirup should be boiled to obtain the best grades of sirup. Not more than a $1\frac{1}{2}$- to 2-inch layer of juice should be in the pans or evaporator at any time, and with care even a thinner layer might be successfully carried. A thin layer makes a quick evaporation and, as a consequence, less color is developed when concentrating to a sirup. Also when boiling a thin layer the impurities reach the surface more easily, and by constant skimming a clear finished product is obtained. Deep boiling in such an apparatus produces the same effect as in iron kettles, namely, a dark, bad-tasting sirup. If an ordinary gutter is placed along each side of the pans when installed the scum

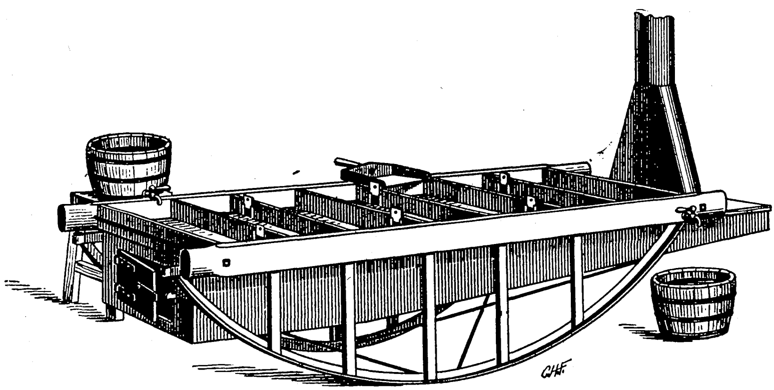

FIG. 16.—A portable evaporator.

can be raked off into this and then caught at the end in a bucket or tub. These skimmings make good food for hogs unless much lime has been added in clarification.

Some makers prefer to boil to a comparatively thin sirup, pass this through a filtering medium to remove the sediment, and then reboil to a proper density. If much lime has been used in clarifying, or if the juice contains much mineral salts, some salts will deposit on concentration. Maple-sirup makers bring much of the floating mineral sediment to the top by adding to the boiling liquid the white of an egg or some whole, fresh, sweet milk, which produces a gelatinous precipitate around the small particles and brings them to the top, where they are removed by skimming. Some sorghum makers do likewise. Under most conditions this material can be removed easily by filtering through flannel or by simply allowing it to settle.

Filtering is rather difficult if the sirup is thick and gets cold; a hot liquid filters faster.

In starting a patent evaporator always have water in all the parts and boil this until the raw juice enters. Never heat kettles or pans without water unless it is desired to burn the scale loose. Even this can generally be done in other ways, namely, by boiling water in the pans, either alone or with some acid, as muriatic acid. The acid, however, must be used with the greatest care, as it dissolves the metal of the evaporator. Scraping with an iron removes the scale but it often spoils the evaporator, causing a leak at the place scraped.

USE OF STEAM EVAPORATORS.

Heating in the steam evaporator is accomplished by means of steam coils. The most common form of such evaporators is a heavy wooden box lined with some metal, as iron, tin, or copper and con-

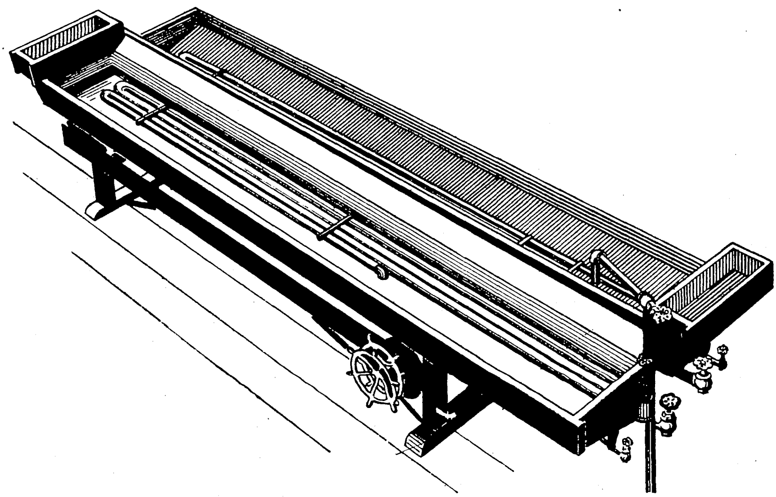

FIG. 17.—A steam evaporator.

taining a coil of iron or copper pipe. The coil is removable so that it can be cleaned. Figure 17 shows a form of steam evaporator used to some extent; one side is for heating the juice, thereby clarifying it, and the other for the concentration. When working on a large scale, copper tanks with copper coils are used. For the small maker it is a question whether steam evaporation pays or not. Although it might pay the farmer who intends to manufacture sirup for others and make it on a large scale to use steam evaporators, fire evaporators that produce 200 gallons of sirup or more in 10 hours of boiling can be purchased. The method of operation with steam heating is the same as with the fire evaporators, but there is much less danger of burning and thereby darkening the sirup by the former process. The level of sirup should be not over half an inch to an inch above the coils for quick evaporation and a good-flavored product.

METHODS OF DETERMINING THE FINISHING POINT.

The finished sirup upon cooling should have a moisture content of not over 30 per cent, equaling a solid content of not less than 70 per cent. One gallon of such a sirup would not weigh less than 11¼ pounds. Commercial practice recognizes this as the minimum density for a sirup. As the sirup comes from the evaporator it is rather difficult to fill and weigh a gallon measure, and again such a weight would be correct only when the whole was cooled down to about 60° F. before the weighing. Some makers determine the finishing point by pouring the sirup from a spoon and watching the last drops fall, but there are two methods which are superior and yet easy to perform. The first is noting the temperature at which the sirup is boiling and the other is to measure the density by means of a Baumé hydrometer.

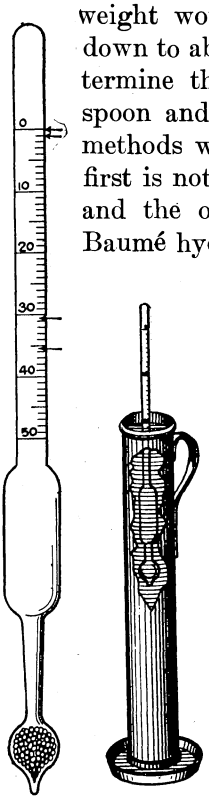

FIG. 18.—Hydrometer and its position in the liquid.

By thermometer.—As a liquid thickens, the boiling point is raised. Water at ordinary pressure or at sea level boils at 212° F., while a sugar solution with 70 per cent of solids boils at 223.7° F. If, now, a thermometer is placed in the boiling sirup one can roughly judge of the density of the product. In testing a sirup for its density by this manner it would be well to test the accuracy of the thermometer by placing it in boiling water and noting the boiling point. Then finish the sirup at a point 12° to 13° higher than the boiling point of water. Altitude affects the boiling point of liquids. For every 500 feet above sea level, roughly speaking, the boiling point is lowered 1° F., so that water at a point 2,000 feet above sea level would boil at 208° F. and a finished sirup at 220° F. In taking the temperature one must be careful not to allow the bulb of the thermometer to touch the bottom or sides of the evaporator or be exposed above the surface of the liquid; otherwise the reading will not represent the true temperature.

By hydrometer.—A hydrometer or spindle is an instrument for showing the density of a liquid. Hydrometers are graduated to various scales and for various purposes. The one generally used for rough sugar work is the Baumé. The standard of graduation is an arbitrary one, and varies somewhat with different makes. The usual Baumé hydrometer shows a graduation of zero to 50 divided into degrees, as shown in figure 18. The instrument being of glass is

rather fragile. The density is measured by floating the hydrometer freely in the liquid, which is generally held in a tall cylinder, as shown in the illustration. The point on the scale where the instrument comes to rest is considered the density. With a raw juice, this varies from 4° to 8°, while for a finished sirup it should be 38° and over.

The temperature of standardization is 60° F., so for correct readings the sirup under examination should be cooled to that temperature. Sirup that gives a reading of from 35° to 36° when at boiling temperature usually gives a reading of 38° or over when it has been cooled to 60° F. The accuracy of these glass hydrometers is very much affected by using them in hot liquids; hence it is not good practice to use an accurate instrument in the hot sirup. Table 2 shows the solid content and the water content for different degrees Baumé. These figures are only approximate.

TABLE 2.—*Dry substance and water corresponding to each degree Baumé.*

Degrees Baumé.[1]	Dry substance.	Water.	Degrees Baumé.[1]	Dry substance.	Water.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
1	1.7	98.3	26	46.8	53.2
2	3.5	96.5	27	48.6	51.4
3	5.3	94.7	28	50.5	49.5
4	7.0	93.0	29	52.4	47.6
5	8.8	91.2	30	54.3	45.7
6	10.6	89.4	31	56.2	43.8
7	12.3	87.7	32	58.1	41.9
8	14.1	85.9	33	60.0	40.0
9	16.0	84.0	34	61.9	38.1
10	17.7	82.3	35	63.9	36.1
11	19.5	80.5	36	65.8	34.2
12	21.3	78.7	37	67.8	32.2
13	23.0	77.0	38	69.7	30.3
14	24.8	75.2	39	71.7	28.3
15	26.6	73.4	40	73.7	26.3
16	28.4	71.6	41	75.7	24.3
17	30.3	69.7	42	77.7	22.3
18	32.1	67.9	43	79.7	20.3
19	33.9	66.1	44	81.8	18.2
20	35.7	64.3	45	83.8	16.2
21	37.5	62.5	46	85.9	14.1
22	39.4	60.6	47	88.0	12.0
23	41.2	58.8	48	90.1	9.9
24	43.1	56.9	49	92.2	7.8
25	44.9	55.1	50	94.4	5.6

[1] Taken at 60° F.

It is not to be understood that a degree Baumé corresponds to 1.7 per cent of sugar, for the hydrometer measures other dissolved solids also. When determining the density of the raw juice, a reading should not be made for about 20 minutes, or until after the hydrometer has come to rest, when all the air in the juice has escaped.

TREATMENT OF FINISHED SIRUP.

When the sirup has reached the desired density it should be quickly removed from the fire and rapidly cooled. If no care in skimming has been exercised during the concentration, the sirup will

have a dirty appearance, and even though carefully skimmed, there may be more or less turbidity due to suspended matter. To completely remove this in many cases is a difficult task, but allowing it to remain in the sirup spoils the appearance and to a less degree the flavor. Many methods have been proposed for removing this material. Some makers filter the sirup, some give it an extra treatment, while others allow the sirup to stand to settle the sediment. A filtration of the semisirup during concentration renders a filtration of the finished sirup unnecessary under most conditions. The greater portion of the sediment is thus removed, leaving only the mineral sediment, which is thrown down by concentrating to a higher density. Again, upon boiling a thin layer in an evaporator and carefully skimming little suspended material is left in the sirup.

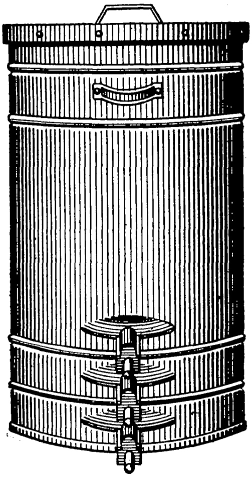

FIG. 19.—A settling can.

Sorghum sirup being particularly viscous at high concentrations does not filter easily through flannel or felt, although when worked hot it can be done. A rather coarse, sharp sand makes a good filter bed. The sand should be carefully cleaned, all organic and soluble material and clay being removed. A bed about 6 inches thick makes a filter that will generally remove the sediment. Some makers use 6 to 8 inches of excelsior or wood straw as a filtering medium. The excelsior should be soaked in hot water to remove all soluble matter before using it for this purpose. Sand or asbestos filters, or in fact any filters, should be carefully cleaned after using. All the remaining sugar solution should be washed out and the bed thoroughly sterilized with hot water or steam. When operating on a large scale, sorghum sirup can be forced through filters under pressure and the maximum cleaning in the minimum time obtained.

If the sirup is not too heavy, standing causes the sediment to collect at the bottom and the clear sirup can be drawn off. For this purpose, tall milk cans with one or two faucets placed 2 and 4 inches from the bottom serve well the purpose. Figure 19 shows such a can with three faucets. The sirup coming from the cooler can be placed in this and allowed to settle. A very heavy sirup, however, or one that is particularly viscous, may stand for as long as a week without any appreciable sedimentation taking place. If the cleansing is carefully done during the process of manufacture the finished sirup will not need much treatment.

Sorghum sirup should be quickly cooled after finishing to hold the color. Many makers run their sirup through a coil of pipe incased

in cold water, which can afterwards be employed advantageously for the boiler when a power mill or steam evaporator is used. Some makers have this coil in their raw-juice tank, which serves the double purpose of heating the raw juice and cooling the finished sirup. Makers who cool their sirup quickly claim that the color is not darkened and a better grade is therefore produced.

CANNING SIRUP.

The form in which the makers offer their sirup for sale depends greatly upon the market conditions. It may be placed in tin containers with screw tops, holding one gallon, one quart, or one pint, convenient sizes for local consumption. When packing in this form, the cans should be thoroughly scalded with hot water before filling. Wooden pails and barrels of various sizes can be used. Wooden packages should be carefully washed out, and for the best after effects should receive a thorough steaming before being filled. Fermentation can be prevented by careful handling of the sirup. Sirup which has been thoroughly sterilized by boiling will not ferment if packed while hot in clean containers which have been sterilized with scalding water or steam and sealed immediately. Care should be taken to have the containers perfectly air-tight; otherwise the sterile sirups may become inoculated with the microorganisms that produce fermentation.

Sorghum sirup may be graded as to color and also flavor by establishing standards on these points and classifying the output. This is of extreme importance in supplying a local market, and it might be of value to the makers of sorghum sirup in a certain locality to unite and sell their product under such conditions. The usual buyer of such a commodity desires two purchases of the same material to have the same color and flavor. They are not informed as to why manufacturing conditions affect these and why all sorghum sirup is not of the same appearance and taste. By having such an association of farmers and a system of standardization, different products can be classified. As maple-sirup makers have found this plan of value, it might be profitably applied to the sorghum-sirup industry.

PREVENTION OF CRYSTALLIZATION.

Crystallization results from making a supersaturated solution of a substance in a liquid. In the case of sirups the sucrose becomes concentrated to a point at which it is no longer soluble in the water present, and hence it crystallizes out. This is the fundamental principle of recovering or manufacturing sugar. In these processes every care is taken to prevent the destruction of sucrose during manufacture so that a greater yield of sugar will be obtained. If sirup is the product to be made on concentration it would be natural for a crystalliza-

tion to take place, and to prevent this crystallization as far as possible the following precautions are taken:

Sucrose, on being heated in the presence of an acid or on long and high heating in water, becomes broken down into two sugars. One of these is crystalline in form; the other is liquid under most conditions. These two sugars are known as invert sugar and possess a sweet taste. The modification of the process referred to is to leave the juice after clarification more acid than in ordinary work. In other words, to use less lime or none at all for clarification. On concentrating such a juice a natural inversion of the sucrose takes place, and hence there is less crystallization. This may suffice in most cases, but when the sorghum is very ripe (has a high sucrose content) the sirup may still crystallize. Some makers accomplish the desired inversion by allowing the cane to remain in the field for 24 hours or

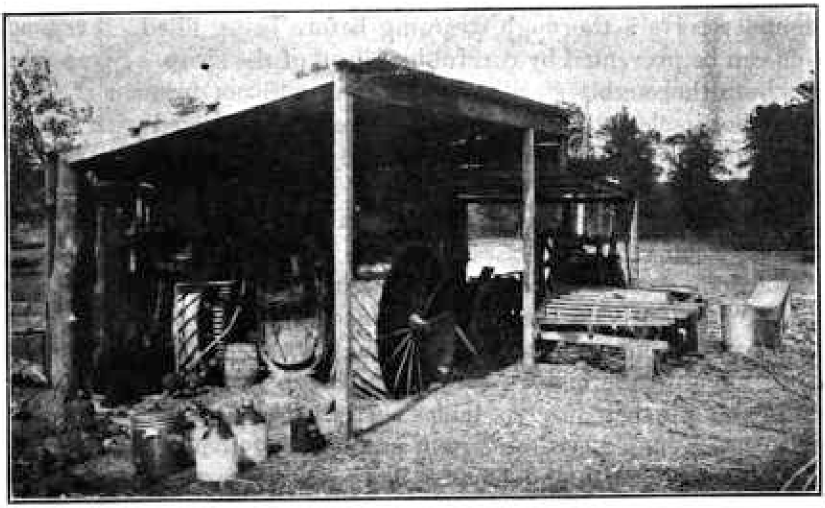

FIG. 20.—Traction engine and cane mill.

more after cutting. This practice reduces the amount of sucrose in the cane, but its effect on the flavor of the resulting sirup is a matter of conjecture. It is, however, done extensively in sorghum-sirup manufacture, and many producers state that the flavor of the sirup is not impaired by this treatment unless the cane has been cut for such a length of time that fermentation has begun. Sorghum juice as expressed from the cane contains some little starch and gummy material. If these are not removed in the process of settling and clarification, they tend to keep a sirup from crystallization, especially if the starch becomes soluble by boiling. It is not the usual policy, however, to allow them to remain in the juice for this purpose (though they are sometimes present, due to poor settling and skimming), as they influence the flavor of the sirup. The danger of crys-

tallization in sorghum sirup is much less than in cane or maple sirup. Long standing, however, in a cool place may cause crystals of sugar to form.

ECONOMIC CONSIDERATIONS.

LOCATION AND ARRANGEMENT OF A SIRUP PLANT.

The small maker should consider carefully the location and arrangement before putting up a plant, as these points are most essential to economy in manufacture. It is impossible to enter into a very thorough discussion of this subject or to lay down hard and fast rules, as many circumstances might affect one's decision. It is certain that the boiling house, etc., should be made easily accessible for bringing in the cane and fuel and storing and taking care of the finished product. In a small plant it is not necessary to cover all the

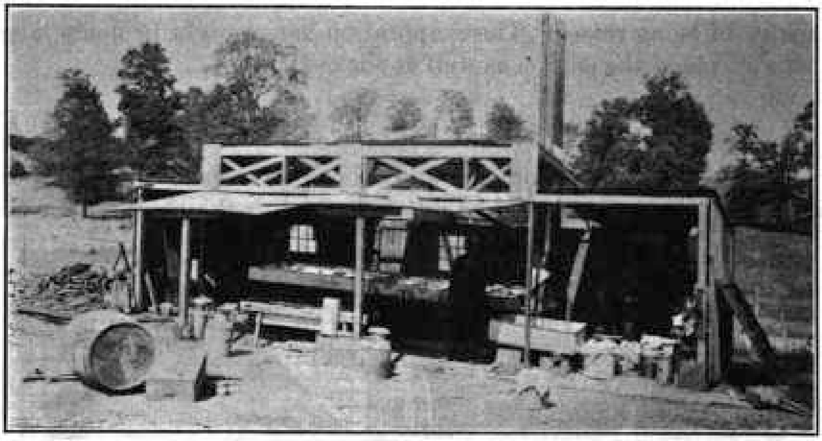

FIG. 21.—Evaporation house.

equipment. The mill should be placed on the highest level, the raw juice caught at a lower point, and the evaporator be placed lower. In this way gravity is made to play an important part. This same idea can be carried out with power mills. In manufacturing on a larger scale the mill is best placed on the ground, the raw juice is pumped into storage tanks placed higher up, from which it runs down through the clarifiers to the evaporators on the ground floor.

The boiling house under all conditions should be covered and provided with a good ventilator in the top to dissipate the steam, and should be inclosed on all sides to prevent the blowing of cold drafts of air on the pan, thus retarding evaporation. It is advantageous to have sections of the siding hinged at the top in such a manner as to allow them to be opened outward, as indicated in figure 21. These sections may then be regulated to facilitate the removal of steam without permitting the entrance of an undue

amount of cold air. A good form for such a structure is shown in figure 21, one of the sides of the house being raised up to form an awning which when let down still allows for a passageway around the evaporator. If possible the floor of the boiling house should be paved with brick, wood, or cement, and sloped to furnish drainage. If a fire evaporator is used it would be well to have a partition at the fire door so that when stirring the fire or adding new fuel no ashes would get into the sirup. In a word, the arrangement should be such that the evaporation can be carried on with dispatch and under cleanly conditions. Many makers use their maple camps for making sorghum sirup also. The same camp and arrangements will serve admirably for the two, providing the location is convenient.

A power mill should be covered; in fact, it could well be placed in a house similar to the boiling sheds shown in figure 21, with sides capable of being raised. The evaporation house might be made large enough to hold the engine as well as the mill.

FUEL.

The fuel for the evaporation and other processes is a very important item. That one should be selected which is the cheapest for the

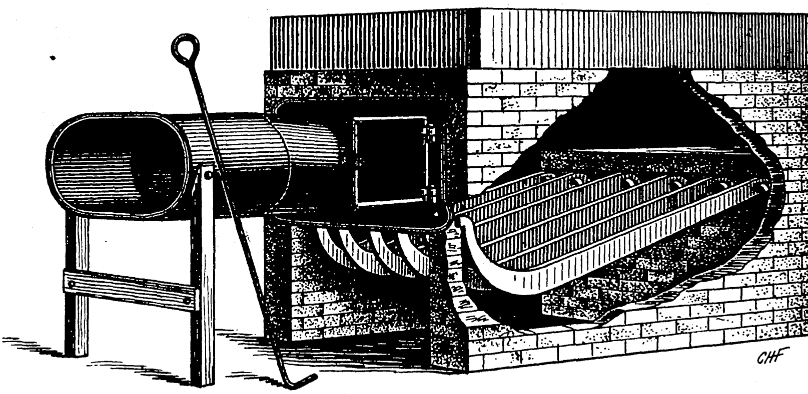

FIG. 22.—A bagasse burner.

work to be done, whether it be wood, coal, or oil. A number of makers use a crude-oil burner under their evaporators; this, in connection with a jet of steam, gives a good fire for evaporation and one capable of adjustment. Many trials have been made in using the crushed cane (bagasse) as it comes from the mills as a fuel, but a special fire box is necessary for this purpose (fig. 22).

The greatest trouble with bagasse is its high moisture content, as the usual mill does not press the cane dry, but by spreading the crushed cane out in the sun a good fuel can be obtained. In the

sugar-cane industry of Cuba the bagasse furnishes in many cases from 90 to 100 per cent of the fuel for operating the whole plant; in Louisiana it furnishes from 50 to 80 per cent of the fuel. The bagasse in these two places is drier than that obtained by sorghum makers unless a series of powerful mills is used. Again, these large cane plants are equipped with special furnaces for handling the bagasse.

Figure 22 shows an arrangement for burning bagasse on a small scale under pans or evaporators. It consists of a sheet-iron funnel tapering toward the end nearest the furnace, so as to compress this light fuel slightly as it is pushed through into the furnace, and having a sheet-iron door hinged to the upper surface. This is a safer and better method of firing than to put the crushed canes directly upon the fire. A fork full of the fuel pushes the door inward, and the door closes itself when the fork is withdrawn.

Another form consists of a small oil burner in the furnace, the bagasse being fed to the fire by hand. There may be some danger, however, in this kind of firing.

MAKING SIRUP ON SHARES.

It quite often occurs that a farmer may grow sorghum but does not care to manufacture it into sirup. Upon what basis should the sirup be made? A central factory seldom raises all its own cane—it buys from the farmers. In this case the agreement is generally drawn up for the cut cane, free of trash, and either stripped or not stripped of leaves at a given price per ton of raw material. On a small scale this is seldom done, one of two general methods being followed in such cases. Either the maker produces the product at a stated price per gallon for the farmer or on shares; that is, giving the farmer a certain number of gallons of sirup (5 to 15) for each ton of cane. In either case it is necessary to keep the cane separate and the juice also, even up to the boiling if the farmer is to receive his share of sirup.

There is, however, a way of approximately determining the amount of sirup that will be made from the cane. By using this method it is not necessary to boil each lot separately, but only to grind the cane separately and then collect the raw juice in tanks where it can be measured. From the gallons of raw juice and its Baumé reading the gallons of sirup that will be made can be calculated.

The settling tanks are convenient for measuring the raw juice. If the tank is oblong or square, take the inside dimensions, length and width, in inches, multiply these together and divide the result by 231 cubic inches to obtain the gallons of juice in the tank for each 1 inch of depth. By inserting a stick or rule in the tank the number of inches of juice is obtained, and this figure multiplied by the gallons per 1 inch of depth gives the number of gallons of raw juice.

If the measuring tank is round, to obtain the gallons of juice for 1 inch multiply the diameter expressed in inches by itself (in other words, square the diameter) and then multiply this figure by 0.7854; divide the result by 231 cubic inches, and the result is the gallons of juice contained in 1 inch of height.

The other figure necessary for the calculation is the density of the juice as determined by means of the Baumé hydrometer. This instrument can be placed in the tank, provided the juice is deep enough to allow it to float freely. From these two figures the yield can be obtained. One maker, Mr. A. P. Cleland,[1] has found that 10 gallons of juice with a reading of 6° Baumé make 1 gallon of finished sirup; from this he calculated the following sliding scale:

Juice, degrees Baumé.	Gallons of juice per gallon of sirup.
6	10
6½	9
7	8½
7½	8
8	7½
8½	7
9	6½
10	6
11	5½
12	5

It is noted that the gallons of juice multiplied by the Baumé reading gives approximately 60 in each case. Each maker can and should prepare for himself such a table as his method of manufacture may not be at all like the one cited. To do this it is necessary to measure several tanks of juice and obtain their Baumé reading, then concentrate the juice to a sirup in the usual way and measure the finished sirup. By multiplying the Baumé reading of the juice by the number of gallons of raw juice and dividing by the number of gallons of finished sirup made, the figure on which to base the table (60 in the case just cited) will be found. With this beginning a table can be prepared for different Baumé readings on the raw juice. In this way as soon as a separate lot of cane is ground the juice can be measured, the density determined, and the number of gallons of sirup due the cane grower can be learned without interfering with the work of the evaporator.

EFFECT OF STRIPPING UPON SUGAR CONTENT OF JUICE.

The effect of stripping the cane is indicated in Table 3. These figures were obtained by dividing a quantity of cut cane into two portions, one of which was carefully stripped, milling the two samples in succession, and obtaining a representative sample of juice from each for analysis.

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[1] U. S. Dept. Agr., Farmers' Bulletin 135, p. 39.

TABLE 3.—*Analyses of sorghum, stripped and unstripped, arranged according to varieties.*

Variety and condition.	Degrees Baumé.	Sucrose.	Invert sugar.	Total sugar.
		Per cent.	*Per cent.*	*Per cent.*
Sumac:				
Unstripped	7.4	4.14	7.57	11.71
Stripped	7.6	4.74	7.50	12.24
McLean:				
Unstripped	9.2	5.28	11.39	16.67
Stripped	11.1	13.76	6.66	20.42
Mixed:				
Unstripped	8.65	7.39	9.29	16.68
Stripped	8.4	9.01	6.82	15.83
Honey:				
Unstripped	6.4	2.83	7.92	10.75
Stripped	6.4	3.20	7.23	10.43
Mixed:				
Unstripped	7.9	4.57	9.02	13.59
Stripped	7.9	5.96	7.43	13.39
McLean:				
Unstripped	9.3	3.19	11.95	15.14
Stripped	10.2	12.14	4.23	16.37
Mixed:				
Unstripped	8.1	4.83	8.58	13.41
Stripped	8.0	5.73	7.63	13.36
Honey:				
Unstripped	6.2	0.22	10.50	10.72
Stripped	6.3	2.32	8.42	10.74
Average:				
Unstripped	7.89	4.06	9.53	13.58
Stripped	8.24	7.11	6.99	14.10
Average, excluding the McLean samples:				
Unstripped	7.44	4.00	8.81	12.81
Stripped	7.43	5.16	7.51	12.67

It will be noted that with each variety the percentage of invert sugar is greater in the juice from the unstripped cane than in that from the stripped cane, while the percentage of sucrose is greater in the case of the stripped cane than in the case of the unstripped. This is shown very clearly in the averages. With the exception of the McLean cane, which possessed large, heavy, green leaves, the difference between the percentage of total sugars is very slight. It seems, then, that there is no material difference in the quantity of sirup that could be produced from a given amount of juice from either stripped or unstripped cane, unless the blades are very abundant and full of juice. As noted in the section on crystallization (pp. 27 and 28), it would appear that allowing the leaves to remain tends to prevent crystallization of the sirup, due to the increased amount of invert sugar in the juice. As stated on page 10, however, allowing the blades to remain tends to make clarification more difficult and may impart a bad flavor to the juice and resulting sirup; also, when the leaves become dry more or less loss of juice through actual absorption by the dry blades during milling may occur. It is believed that where the cane is cut with the leaves still attached and allowed to remain in the field for about 24 hours, a portion of the juice of the leaves returns to the stalk as the leaves wither, with a corresponding increase in the amount of invert sugar in the juice finally obtained. For the reasons already given, however, the leaves should be removed before milling.

BY-PRODUCTS AND THEIR USES.

Bagasse.—The crushed cane as it comes from the mill is known as bagasse, the use of which as a fuel has already been discussed (p. 30). It is also of value as a fertilizer and when spread over fields and plowed under restores a certain amount of the fertilizing ingredients taken from the soil by the plant. In some sections it is customary to give cattle access to the bagasse which has been spread over the fields, care being taken not to let them eat too much of it at first. Bagasse mixed with varying percentages of cottonseed meal, molasses, etc., has also been used as a dry dairy feed. Although it has been employed as a material in making paper, its use for this purpose has not proved successful enough to warrant establishing the manufacture of paper from it upon a commercial basis.

Leaves and blades.—In stripping the cane from 5 to 15 per cent of the weight of the crop is removed; in other words, the leaves when green weigh on an average about 10 per cent of the topped cane. If they are frostbitten, or dry, or both, they may not be over 4 per cent of the weight of the cane. Some makers on buying cane consider a long ton of unstripped cane equal to a ton of stripped cane—that is, 2,240 pounds are equivalent to 2,000 pounds, which would make the leaves and dirt amount to about 12 per cent. Some varieties bear more leaves than others, so only average figures can be given. The leaves make a good cattle food, or by allowing them to remain in the fields and plowing under they are of more or less value as a fertilizer. The leaves have also been used in making ensilage. Having a tendency to become sour, however, their use for this purpose does not seem entirely satisfactory.

Seed heads.—The amount of seed per acre varies with the variety of sorghum and the stand. Estimates ranging from 5 to 30 bushels to the acre are given, an average figure for the usual varieties of sugar sorghum being about 10 bushels. They have a large feeding value, claimed by some to be equal to corn, but most authorities give them a place much below corn. On account of the shape and hardness of the seed, better feeding results are obtained by first boiling or grinding them. Because of the difficulty of removing the hulls and the astringency of the seed coating, the grain is less relished by animals than is that of the nonsaccharine varieties.

ANALYSES OF SORGHUM VARIETIES.

The results of analyses of cane grown in locations during the year 1910 are given in Table 4. The data include the Baumé reading and the percentages of sucrose and invert sugar in the expressed juice.

The samples of Collier and Coleman cane show very high percentages of sucrose with rather low invert sugar content. It is doubtful

whether the average run of sorghum cane of these varieties gives such high figures, but they serve to show the results that may be expected when the cane is produced under favorable conditions.

TABLE 4.—*Analyses of sorghum, made in 1910, arranged according to varieties.*

[Results are analyses of expressed juice.]

Variety and locality.	Degrees Baumé.	Sucrose.	Invert sugar.	Total sugar.
		Per cent.	*Per cent.*	*Per cent.*
Sumac:				
Biloxi, Miss	8.1	4.07	7.37	11.44
Do	10.1	10.93	3.21	14.14
Dalhart, Tex	10.6	11.34	3.49	14.83
Do	8.6	2.88	10.90	13.78
Brownsville, Tex	9.0	8.52	4.74	13.26
Do	8.0	4.26	6.70	10.96
Planters:				
Biloxi, Miss	9.7	10.59	1.91	12.40
Arlington, Va	9.7	2.98	10.70	13.68
Do	11.3	4.15	11.69	15.85
Compton, Cal	9.7	9.27	3.28	12.55
Monette, S. C	11.6	14.47	2.84	17.31
Do	12.2	15.38	1.74	17.12
Brownsville, Tex	7.3	5.58	3.86	9.44
Do	7.9	8.22	2.05	10.27
Dalhart, Tex	8.4	4.15	5.78	9.93
Do	8.6	3.17	6.54	9.71
Red amber:				
Biloxi, Miss	9.3	9.57	2.72	12.29
Arlington, Va	9.2	0.75	12.57	13.32
Do	10.0	3.02	11.65	14.67
Monette, S. C	10.4	6.41	8.70	15.11
Compton, Cal	11.9	1.43	14.46	15.89
Dalhart, Tex	6.3	1.88	6.32	8.20
Brownsville, Tex	8.3	4.64	6.87	11.51
Do	7.4	1.81	7.64	9.45
Minnesota amber:				
Biloxi, Miss	10.7	12.89	1.72	14.61
Arlington, Va	10.0	3.54	11.15	14.69
Do	10.5	4.26	11.40	15.66
Compton, Cal	7.5	5.77	2.95	7.72
Monette, S. C	10.7	13.00	2.03	15.03
Dalhart, Tex	7.4	4.98	4.54	9.52
Do	8.5	4.82	6.78	11.60
Brownsville, Tex	7.2	5.01	4.18	9.19
Do	8.0	4.37	6.98	11.35
Orange:				
Biloxi, Miss	10.3	12.32	1.88	14.20
Arlington, Va	8.1	2.86	7.35	10.21
Do	10.5	1.66	14.62	16.28
Compton, Cal	9.2	7.99	3.38	11.37
Monette, S. C	....	14.30	1.75	16.05
Do	12.7	15.53	2.14	17.67
Dalhart, Tex	6.2	1.70	5.72	7.42
Brownsville, Tex	6.8	2.64	5.91	8.55
Do	9.6	8.14	5.35	13.49
Honey:				
Biloxi, Miss	8.6	8.22	4.44	12.66
Arlington, Va	11.0	3.58	13.57	17.15
Do	11.2	11.46	4.48	15.94
Compton, Cal	11.6	12.59	1.50	14.09
Dalhart, Tex	9.7	1.73	11.97	13.70
Brownsville, Tex	8.3	5.66	5.78	11.44
Do	8.7	8.44	3.42	11.86
Gooseneck:				
Biloxi, Miss	8.9	8.67	4.42	13.09
Arlington, Va	8.7	3.84	8.80	12.64
Compton, Cal	8.5	7.39	2.91	10.30
Dalhart, Tex	10.5	10.48	4.63	15.11
Colman:				
Compton, Cal	11.9	13.79	1.12	14.91
Monette, S. C	....	15.30	1.28	16.58
Do	11.2	14.25	1.93	16.18
Collier:				
Compton, Cal	10.9	12.14	2.12	14.26
Monette, S. C	13.7	18.39	0.61	19.00
Do	14.0	18.24	0.92	19.16
Average	9.6	7.61	5.61	13.22

STATISTICS.

The figures in Table 5 were obtained from the United States Census reports. These figures are only approximately accurate, as it is quite impossible to obtain exact data owing to the fact that much of the sorghum sirup is made upon a very small scale and probably not reported. If such sirup were included, the totals would be greater.

It will be noted that a maximum yield of nearly 28,500,000 gallons was produced in 1879 and that the yield has steadily decreased, approximately 16,500,000 gallons having been produced in 1909. The production in some States has decreased rapidly since 1879, as, for instance, Iowa, Illinois, Missouri, Ohio, and Kansas, while in other States—Kentucky, Tennessee, Arkansas, North Carolina, and Texas—it appears to remain about the same. The production in 1909 shows an increase over that of 1879 in comparatively few States, namely, Oklahoma, Texas, Florida, New Mexico, California, Nevada, Montana, and North Dakota. Arkansas and North Carolina also show an increase, though not so great a one as in 1889 and 1899. The nonproduction of sorghum sirup in Maine, New Hampshire, Vermont, Massachusetts, and Connecticut, and the marked decrease in production in New York, Pennsylvania, Ohio, and Michigan is probably due to the fact that all of these States are large producers of maple sirup and sugar.

TABLE 5.—*Gallons of sorghum sirup produced (United States Census reports).*

States.	Year of census report.					
	1909	1899	1889	1879	1869	1859
Kentucky	2,733,683	1,277,206	2,094,962	2,962,965	1,740,453	356,705
Tennessee	2,076,339	2,047,655	2,542,533	3,776,212	1,254,701	706,663
Missouri	1,788,391	1,990,987	2,721,240	4,129,595	1,730,171	796,111
Arkansas	1,140,532	1,223,691	1,868,952	1,118,364	147,203	115,604
North Carolina	1,099,346	1,419,570	1,268,946	964,662	621,855	263,475
Illinois	977,238	625,939	1,110,183	2,265,993	1,960,473	806,589
Indiana	965,086	579,061	751,808	1,741,853	2,026,212	881,049
Alabama	809,361	1,168,868	1,242,689	1,163,451	267,269	55,653
Georgia	740,450	767,024	1,342,803	981,152	374,027	103,490
Mississippi	622,356	1,162,269	972,216	1,062,140	67,509	1,427
West Virginia	604,201	450,777	512,747	817,168	780,829	....
Oklahoma	514,807	179,272	31,299	....	....	....
Texas	448,185	877,232	1,749,910	432,059	174,509	112,412
Virginia	441,189	555,321	546,328	564,558	329,155	....
Ohio	354,131	341,523	547,630	1,229,852	2,023,427	779,076
South Carolina	262,452	478,190	559,216	281,242	183,585	51,041
Kansas	260,680	735,787	1,484,937	1,429,476	449,409	87,656
Iowa	250,205	521,212	1,386,605	2,064,020	1,218,636	1,211,512
Minnesota	145,934	157,605	340,792	543,369	38,735	14,178
Wisconsin	139,667	160,414	219,070	314,150	74,478	19,854
Louisiana	47,029	48,727	107,763	33,777	180	....
Florida	22,177	....	10,461	10,199	....	....
Utah	21,847	28,017	24,293	58,221	67,446	25,475
Michigan	21,350	24,059	45,524	102,500	94,686	86,953
Nebraska	14,644	92,413	634,146	246,047	77,598	23,497
New Mexico	5,289	2,812	3,510	251	1,765	1,950
Delaware	4,517	8,952	3,371	25,136	65,908	1,613
California	4,330	8,671	1,670	2,459	333	552
Arizona	3,967	9,031	4,808	5,771	....	....
Pennsylvania	2,585	6,514	33,708	69,767	213,373	22,749

TABLE 5.—*Gallons of sorghum sirup produced, etc.*—Continued.

States.	Year of census report.					
	1909	1899	1889	1879	1869	1859
Colorado	2,547	2,661	19,964	3,227		
South Dakota	2,030	9,859	29,372			
Maryland	1,782	4,058	4,732	19,837	28,563	907
Oregon	1,374	2,473	2,706	2,283		315
Nevada	1,266	1,465	930	350	3,651	
Washington	634	438	1,125	1,472	612	
Idaho	407	1,393	3,093	36		
Montana	223	100				
North Dakota	102	114	10			
New Jersey	35	450	281	1,261	17,424	396
New York	14	973	8,305	1,134	7,832	516
Wyoming			120			
Connecticut			214	1,163	6,832	395
Maine			152			
New Hampshire			50			
Vermont			45			
Massachusetts				18		
Total United States	16,532,382	16,972,783	24,235,219	28,444,202	16,050,089	6,749,123

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